Physics Requirements for a Medium Acceptance Device with 11 GeV beam

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With the Jefferson Lab 12 GeV (11 GeV for Halls A, B and C) upgrade, several new physics windows open up. In particular, a large kinematics domain in deep inelastic scattering becomes available. Coupled to the high luminosity and high polarization of beam and targets, Jefferson Lab will be in an unique position to make a significant contribution in the understanding of nucleon and nuclear structure, and strong interaction in the high x region. (For a non-expert, roughly speaking x is the percentage of momentum carried by the leading quark with which the electron is directly interacting). Theoretically, the high x region is relatively clean, where it provides a testing ground for our understanding of the nucleon structure in terms of a simple quark picture. Due to the fact that the quark distribution drops fast when x becomes large, few precision data exists in this region (especially for the spin-dependent nucleon structure). Precision data in this region (at relatively low Q^2) are not only important for understanding the structure there, but also have a significant impact for a search of new physics beyond the standard model at very high energies. A high luminosity is crucial for getting precise information in this region to test our understanding. The high luminosity of CEBAF alone is not enough to fully explore the high x region. A well matched spectrometer is crucial for the high impact physics program in the high x region.

Table 1 lists the physics requirements of a number of experiments in the high x region. A brief explanation of the experiments being considered is given in the following paragraphs.

From the listed experiments, it is concluded that a spectrometer with the following parameters will be an instrument tailored to this physics program:

Angular acceptance of 30 msr (at a scattering angle of 30°) to 15 msr (at 15°);
Momentum acceptance of 30%;
Maximum central momentum of 5-7 GeV/c;
Minimum scattering angle of 12-25° (reduced solid angle at small angles);
Moderate resolutions of 0.3% *in momentum, 1 mr (3 mr) in horizontal (vertical) angle.*

In table one, the first experiment uses unpolarized inclusive electron scattering on ^{3}H and ^{3}He[1]. By studying the ratio of the structure function on ^{3}H to ^{3}He, minimizing the effect of nuclear corrections, it will be able to measure precisely the down quark to up quark ratio at high x. It will resolve a long-standing issue of different prediction from pQCD with constituent quark models.

The second will be a first precise measurement of the spin structure function g_1 and A_1 of the neutron by using a polarized ^{3}He target[2]. It will unambiguously demonstrate the trend of A_1^n to go to 1 or 0 when x goes to 1. It will be a benchmark test of pQCD and constituent quark models. A deviation of the approaching to 1 will be a signature of new physics. Also the detail of how A_1 approaches 1 can be related to the transverse polarization of the quarks, which is of great interest to the understanding of the structure and interactions in the nucleon. The precision measurements of g_1 will provide vital information on the nucleon spin structure.

The third experiment is to measure the g_2^n spin structure function and its moments[3]. This measurement will be a clean measure of the so called "higher twist" (twist 3) effect, which is related to the quark-gluon interaction.

The 4th one is similar to the 2nd, except to study the proton instead of the neutron[4]. The 5th one is using parity-violating experiments to study nucleon structure, quark-quark correlations and the standard model[5].

With the high luminosity and well matched spectrometers, another window opens up in the study of the nucleon structure and strong interaction: the semi-inclusive reaction to probe the structure of the parton distributions. The next two experiments are examples of a very rich program using semi-inclusive reactions to test the factorization, to study the flavor decomposition of the nucleon spin structure, the asymmetry of the sea quark distribution, and the skewed parton distributions[6].

With an 11 GeV beam, another threshold is crossed: the charm production. Threshold charm production[7] opens up another window to study the role of the gluons in the nucleon structure and some other novel phenomena, such as hidden color. Also a measurement of the charm-nuclear cross sections will provide important information for RHIC physics.

The measurement of b_1[4] studies the spin 1 system with a tensor-polarized deuteron target, provides an unique channel to study the difference of deuteron system from a trivial bound state of two spin 1/2 objects coupled to spin 1.

The last one listed is one of the experiments measuring the recoil proton polarization[6], which can be used to study both the nuclear structure and the nucleon structure.

Many other experiments not listed in table 1, such as Real and Deep Virtual Compton Scattering[8], will also benifit from such a spectrometer.

References

[1] G. Petratos, presentation at this workshop

[2] Z. E. Meziani, presentation at this workshop

[3] T. Averett, presentation at this workshop

[4] J. Mitchell, presentation at this workshop

[5] P. Souder, presentation at this workshop

[6] R. Gilman, presentation at this workshop; P. Mulders, presentation at this workshop; H. Gao, private communication

[7] E. Chudakov, private communication

[8] B. Wojtsekhowski and C. Hyde-Wright, private communication

Table 1: Medium Acceptance Device Requirements

Exp	P_{max} (GeV/c)	Solid angle (msr)	Acc (P) %	Res(P) %	Res H.Ang (mr)	Res V.Ang (mr)	Min. Angle	Comm.
$^3H/^3He$	6	15-30	30	0.3	1	3	15-30	F_2,R
A_1^n, g_1^n	5-7	15-30	30	0.3	2	3	15-30	W,Q^2
g_2^n	5	20-30	30	0.3	2	3	15-25	d_2^n
A_1^p, g_1^p	5-7	15-30	30	0.3	2	3	15-30	W, Q^2
DIS-PV	6	30	30	0.3	1	3	15-25	d, p
semi-pi	6-7	10-30	30	0.3	2	3	12-15	
semi-K	6-7	10-30	30	0.3	2	3	12-15	
charm	6.5	30	30	0.3	1	2	12-15	
b_1	6	15-30	30	0.3	1	3	20-30	spin 1
Rec. P	5-7	10-30	30	0.3	1	3	15-25	A